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Human Dietary Fibre : A Review

C. H. FORBES-EWAN

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6 # HUMAN DIETARY FIBRE: A REVIEW (U)

10 C. H. FORBES-EWAN

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SUMMARY

A review is made of the composition, analysis and relationship to disease of fibre in human nutrition. (U)

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CONTENTS

HUMAN DIETARY FIBRE

A REVIEW OF THE COMPOSITION, ANALYSIS AND RELATIONSHIP TO DISEASE OF FIBRE IN HUMAN NUTRITION

Definition of Fibre

The term "fibre" is at present an imprecise term. The concept arose initially to denote that component of a forage crop which was unavailable to animals. This was referred to as "crude fibre".

Crude fibre analysis consists of extraction with petroleum ether, followed by acid, then alkali digestion (i.e. simulating animal digestion). The undigested residue is weighed, ashed and the crude fibre value is the final residue weight minus the ash weight (Horwitz, 1970).

The concept of "fibre", particularly in relation to human nutrition has altered over the years, until now "fibre" is considered to be the whole of the plant cell wall plus some substances such as mucilages and gums which are not found in the cell wall but which are indigestible in the human gut. Not all plant cell wall constituents are indigestible though, so fibre is not completely indigestible, and not all the constituents of "dietary fibre" are, in fact, fibrous. (Cummings, 1973).

The crude fibre analysis described above is extremely method-dependent and insensitive at the low fibre levels found in many foods (van Soest, 1963). It also measures a very variable proportion of the total plant cell wall constituents, which are invariably underestimated. Crude fibre analysis recovers 50-80% of the cellulose, 10-50% of the lignin and only about 20% of the hemicelluloses (van Soest, 1973). The proportion of the total cell wall constituents recovered depends to a large extent on the percentage of hemicellulose present. Hemicelluloses are largely lost in the crude fibre analysis.

The crude fibre method thus has many deficiencies and does not have a place in the analysis of dietary fibre in human foods.

Alternative methods of analysis will be discussed later.

Components of Fibre and their Possible Physiological Significance

(1) **Cellulose.** This is the only truly "fibrous" component of the cell wall. This is an unbranched 1-4B-D-glucose polymer containing about 3000 glucose units. The whole molecule folds into a flat, ribbon-like structure which packs closely with identical molecules to form micro-fibrils. These form the fibres of cellulose which are woven into the plant cell wall (Ranby, 1969).

The fibres are very strong due, it is believed, to the length of the chains and hydrogen bonding between hydroxyl groups of adjoining polymers (Jeffrey

and Rosenstein, 1964). For the most part, cellulose is crystalline, but there are regions along the micro-fibrils which are non-crystalline (amorphous).

In terms of significance to human nutrition, the most important properties of cellulose are the susceptibility of the molecule to enzymatic and acid hydrolysis, and its ability to absorb water. Both these characteristics appear to involve the amorphous areas of the microfibrils. Cellulose is susceptible to acid hydrolysis and is 30-40% digested (Mangold, 1934).

Most plant cell walls contain 15-40% pure cellulose on a dry-weight basis (Kent-Jones and Amos, 1967).

Inclusion of cellulose in the diet of both animals and man is associated with changes in cholesterol and bile acid metabolism, however cellulose appears to be less potent than other dietary fibre constituents in lowering blood cholesterol level (Keys et al, 1961).

(2) **Hemicelluloses.** Mostly 5-carbon sugars, they are soluble in cold, dilute alkali. Hemicelluloses are either acidic or neutral depending on whether they have small or large numbers of uronic acid residues. Together with pectin, the hemicelluloses form the matrix of the plant cell wall in which are enmeshed the cellulose fibres.

Of possible physiological significance are: hemicelluloses have a water-holding capacity, are 55-90% digestible (Williams and Olmsted, 1936, Southgate and Durnin, 1970) and bind ions.

(3) **Pectins.** Pectins constitute between 1 and 4% of total cell wall polysaccharides (Whistler and Richards, 1970). The parent molecule is a polymer of 1-4-B-D-galacturonic acid. The parent polymer is usually modified to include 10-25% of neutral sugar residues. Pectins have the ability to form gels and can bind ions. In man, pectins may be almost completely digested (Wersh and Ivy, 1941). Pectins can alter cholesterol metabolism (lowering blood cholesterol level). In man, pectin supplements of 15-35 g per day led to significant lowering of blood cholesterol (Fisher et al, 1965).

In another experiment, pectin supplements were found to be second only to a reduction in dietary intake of cholesterol in reducing blood cholesterol levels (Anderson, 1973).

The degree of methylation of the molecules affects both the degree of gel-formation and the cholesterol lowering ability (Ershoff and Wells, 1962).

(4) **Plant gums, mucilages, storage polysaccharides.** These are not cell-wall components, but are related to them biochemically and in their physiological effects. Mucilages are found in seeds where they protect against desiccation by holding water. Mostly they are neutral polysaccharides.

Structurally, they resemble hemicelluloses. Guar is an example; in small amounts it is used as a food thickener.

Gums form at the sites of injury in plants. In the food industry they are used as stabilizers, emulsifiers, thickeners and in bulk-forming laxatives

Gum arabic is also used as an adhesive.

Gums are a complex group of highly branched uronic-acid-containing polymers, with neutral sugars such as xylose and arabinose. A high proportion of calcium and magnesium salts is formed and a significant number of residues are acetylated (Aspinall, 1970).

In terms of physiological effects on man, the most important characteristics of gums and mucilages are their effects on cholesterol and bile salt metabolism. They have similar effects to pectin. Guar is especially potent (Jenkins et al, 1975).

(5) **Lignin.** This is the atypical constituent of fibre in that it is not a carbohydrate. It is a small, insoluble polymer with molecular weight 1000-4000. It is made up of three different subunits, each of which consists of a substituted phenylpropane (Kent-Jones and Amos, 1967).

Lignin's role in the cell wall is to strengthen it by permeating and supporting the other components (Pearl, 1967). Lignin impairs the digestibility of other cell wall constituents (Raymond, 1969). It is also thought to have a bile-salt-binding capacity, with adsorption perhaps occurring through hydrophobic interactions (Eastwood and Hamilton, 1968).

(6) **Algal Polysaccharides.** Related to the above components of fibre is alginic acid, derived from algae. This is a nonsulphated polysaccharide. In its native form it occurs as sodium, calcium, potassium or magnesium salts (alginates). It is a linear, acid, polysaccharide polymer, largely unbranched so it, like cellulose, can form microfibrils.

Alginic acid is widely used in the food, pharmaceutical and paper industries. In food, it impairs the absorption of strontium in the gut (Patrick, 1967).

(7) **Fibre-associated substances.** Methods of fibre analysis invariably leave some non-fibre substances in the residue. The extent to which some of the characteristics of fibre are in fact due to these contaminants is not known.

Phytic acid is found in seeds in association with protein. Usually it is complexed with Ca, Mg and K and exists as salts (phytin). Phytin is milled off with the bran during the refining of wheaten flour; it is therefore present in wholemeal bread and not, significantly, in white bread (Kent-Jones, 1967). Because of the ion-binding capacity of phytin, the consumption of wholemeal bread can deplete ions such as calcium from the gut. In areas where calcium intake is borderline, this could lead to osteomalacia (Berlyne et al, 1973).

Phytin is also thought to impair iron and zinc absorption (Jenkins et al, 1976). The principal constituent of the ash in the fibre fraction is silicon. Its significance to human nutrition relates to its capacity to impair digestibility of cell-wall materials. In this respect it bears some similarity to lignin (Raymond, 1969).

Cuticular substances (waxes and cutins) also apparently impair cell-wall digestion (van Soest and McQueen, 1973).

The plant cell wall contains a multitude of other substances whose role in human nutrition is not clear, e.g. tannins, enzymes, vitamins, glycosides, etc.

Conclusion. Fibre is a complex matrix of polymers from the plant cell-wall and similar substances from elsewhere in the plant cell, e.g. gums and mucilages.

The main physiological effects of these individual components are on: cholesterol and bile acid metabolism, water-holding capacity, gel-formation, and ion-binding.

The physical and chemical interactions of the constituents of fibre are important in the context of nutrition, as the components do not exist separately. How the physiological effects of individual components are altered by the presence of other fibre constituents is unknown.

Arrangement and Distribution of the Components of Dietary Fibre in Foods

(1) **Development of the cell wall.** (Albersheim, 1965). After nuclear division of the parent cell, a cell plate forms between the daughter nuclei. This is rich in pectic substances and becomes the middle lamella. The primary wall, which is deposited on the middle lamella, consists of cellulose fibrils that appear to be deposited as a random network. The matrix that forms around these fibrils contains non-cellulosic polysaccharides with both pectic and hemicellulosic characteristics.

The secondary wall usually consists of three distinct layers. Cellulose fibrils are laid down in a regular parallel arrangement. The matrix surrounding these is primarily hemicellulosic.

Lignification usually starts in the middle lamella and then proceeds outwards, swelling the cell wall. The actual composition of the cell wall varies from tissue to tissue and depends on the age of the plant (particularly with respect to lignin). Hirst, et al, 1959):

(i) Stem structures: Most "stemfoods" are consumed in immature condition, are lightly lignified with a cuticular layer on the outer surface. Potato is an example.

(ii) Leaf Structure: These are lightly lignified, have a cuticular layer and a waxy coating. In monocotyledons, heavy lignification occurs.

(iii) Root Structure: These are usually eaten before much secondary thickening occurs. They are therefore lightly lignified, e.g. carrots, turnips.

(iv) Fruits: These vary widely. There are two distinct classes, fleshy (e.g. tomato, citrus) and hard (e.g. nuts). Fleshy fruits are typically thin-walled, with only light lignification.

(v) Seeds. The walls of the cells in the seed coat are often thickened and frequently lignified. In some, mucilages are present which absorb water and swell, thus rupturing the seed coat and cuticle (i.e. germinating).

The Analysis of Dietary Fibre

As mentioned in Section (a), the "crude fibre" analytical method is not applicable to human dietary fibre with any degree of precision.

As yet, no one method is available which can be used on all foods without modification.

The "acid detergent fibre" (ADF) method of van Soest (1963) provides an estimate of fibre that correlates closely with the nutritive value of ruminant feedstuffs. The fraction measured by this procedure has been shown to consist mainly of cellulose and lignin. It also contains some silicon.

The method has a number of limitations when applied to human foods (Southgate, 1976). Human foods are usually much higher in lipids and starch than animal forage crops; this leads to problems of foaming and filtration. A more fundamental problem is that the ADF method measures only a fraction, albeit a significant one, of the components of human dietary fibre.

The "neutral detergent fibre" (NDF) method also of van Soest (1963) is thought to give an accurate measure of the cell wall constituents of vegetables

According to Southgate (1976) it appears to divide the dry matter of feeds very nearly into those constituents which are nutritionally available to man and those which depend on microbial fermentation.

The method involves extraction of non-fibre components of food in a neutral detergent followed by filtration and ashing of the residue to correct for inorganic contamination of the fibre.

The main problems (Southgate, 1976) are:

(1) Imprecision due to small sample size. If a larger sample is used, problems of foaming occur. This can be largely overcome by initial lipid extraction.

(2) Starch can remain insoluble in the hot detergent and be measured with residual NDF. Enzymatic hydrolysis can correct for this.

(3) A fundamental problem is that the method will underestimate total dietary fibre because the water soluble polysaccharides are lost during the extraction. Angus et al (1977) on the other hand, claim that the NDF method leaves as fibre appreciable quantities of material susceptible to digestion by mammalian digestive enzymes.

They propose a method based on the NDF technique which includes water, ethanol and ether extraction and pancreatin digestion, as well as the neutral detergent extraction.

Their results were consistently lower (i.e. they obtained less fibre) than those obtained using the NDF method.

McCance et al (1936) measured "unavailable carbohydrate", a fraction which corresponds closely to dietary fibre, in a range of fruits, nuts and vegetables. They determined the residue insoluble in 80% v/v ethanol and then measured the starch in the residue after enzymatic hydrolysis with a takadiastase prepartion; they then corrected for protein in the residue.

Southgate and Durnin (1970) developed methods to measure the various components of the unavailable carbohydrate fraction and thus form a basis for the measurement of dietary fibre. The method is, of necessity, very time-consuming and could not be used for routine analytical work. The first part of the method, however, gives a similar estimate of total dietary fibre to the method of McCance et al (1936). Southgate's method is based on an alcohol-insoluble residue, with starch removed by enzymatic hydrolysis and fat removed by diethyl ether extraction.

Conclusions: No method of analysis for dietary fibe has yet reached the stage of an accepted, standard method, applicable to all, or a majority of human foods. Modifications of the NDF method and the initial stages of the Southgate method seem to offer the best promise of a routine method.

Possible Modes of Action

Vegetable fibre is a physical complex that acts principally in the colon. Fibre has water-holding, cation exchange and adsorptive properties, which vary with the variety of fruits and vegetables studied. It is possible that vegetable dietary fibre acts in the colon by forming a supporting matrix which provides surfaces or a locating micro-environment in which bacteria and intestinal contents interact (Eastwood and Mitchell, 1976). Vegetable dietary fibre may also act as a gel with partitioning characteristics for both bacteria and other substances in the intestinal contents. The metabolism of substances in the colon in its turn is influenced by the physical characteristics of the matrix, and this supporting medium may be metabolized and its character changed by the activity of the bacteria. There are important effects of fibre on solute and bacterial activity, which influence the fate of bacterial metabolites of solutes of endogenous and exogenous origins. Such effects may decide whether the metabolites are excreted in the faeces or are conserved by being returned in the portal vein. Fibre itself may be metabolized by bacteria (Wersh and Ivy, 1941).

It is possible to protect against the carcinogenic effect of chemical carcinogens by inducing increased mixed-function oxidase activity. The level of mixed function oxidase activity in the small intestine is related to the amount of fibre in the diet. The factor(s) is not known, but it could be lignin which does act as an antioxidant in the digestive tract (Wattenberg, 1974).

The significance to the human host of the colonic microbial activity is not clear. The acids formed in the posterior gut by fermentation of protein may have value, and vitamin synthesis may be important, but many nitrogenous products of dubious or negative value are also formed, in contrast to the fermentation products from carbohydrates (i.e. in herbivores such as ruminants) which give rise to volatile fatty acids which are absorbed by the host and oxidized to provide energy (Hungate, 1976).

Theories on the Health-Benefiting Role of Fibre in Diets

(1) Fibre functions as a Bulking Agent: Undigested, high molecular weight compounds form faecal bulk. Bulk in the intestinal tract induces a faster transit time and reduces the opportunity for microbial production of toxins or carcinogens. It has been suggested that cancer of the bowel can be due to the production of carcinogens by the action of colonic bacteria on compounds present in the colon, e.g. bile acids and steroids (Burkitt, 1974).

(2) Fibre functions as a toxin antagonist: Large, insoluble compounds are ideal absorbants. Dietary fibre could bind potential toxins, prevent their digestion or absorption and facilitate their excretion.

(3) Fibre Functions as a Nutrient: Fibre may be a source of unknown nutrients or compounds that have medicinal properties. Natural plant fibres are a heterogeneous mixture of complex compounds. The chemical structure and biological activity of the individual molecule is often unknown. Even undigested molecules can cause an indirect health benefit by stimulating the growth of beneficial microflora or by retarding the growth of pathogenic organisms (Lang and Briggs, 1974).

Animal Studies. In monogastric animals, e.g. rat, mouse, rabbit, chick and guinea pig, fibre seems to be non-essential, except perhaps in the guinea pig, although it confers benefits to the rat and rabbit and to many other species (Lang and Briggs, 1976).

Conclusion. The debate over the need for dietary fibre has a long history and will undoubtedly continue for many decades. Currently, we must conclude that we have not seen convincing evidence that dietary fibre is an essential dietary component. The development of chemically defined liquid diets for rats, chickens and man suggests that there is no unique, essential function for dietary fibre.

Although dietary fibre may not be an essential component, many studies indicate that it may have health-benefiting properties, such as reducing the effects of toxins, reducing cholesterol levels and preventing diverticular disease. Unfortunately, many of these theories involve slow processes and thus require long-term tests which must be carefully controlled.

Excessive fibre may be harmful, e.g. phytic acid, oxalic acid and phenolic compounds are associated with plant fibres and have have been shown to restrict the availability of essential elements such as zinc (National Research Council, 1973).

In the context of possible benefits conferred by dietary fibre, it is interesting to note that placebos frequently consist of fibrous material, such as carboxymethylcellulose. A consistent proportion of patients has been cured by placebo treatment, a result which is usually attributed to psychological factors. In view of the antitoxic effects of cellulose, perhaps placebos should not contain fibre (Lang and Briggs, 1976).

Dietary Fibre and Lipid Metabolism (Danielsson, 1973)

Cholesterol is a monohydric sterol in every cell in the body It is synthesized mainly in the liver and intestine. The major catabolic products are the bile acids. The bile contains cholesterol, bile salts and phospholipids (primarily lecithin) in a delicate balance. Any substantial change in any one of these can lead to gallstones.

In general, pectin and other polysaccharides are hypo-cholesterolaemic (Kirayama et al, 1969). The suggestion has been made that the mechanism of action of pectin is inhibition of cholesterol absorption and increase of faecal bile acid excretion (Leveille and Sauberlich, 1966). Experiments involving man have not shown a great effect of bran on serum cholesterol level (Connel et

al, 1975). Pectin and guar gum, on the other hand seem to be quite effective in lowering serum cholesterol (Keys et al, 1961). Evidence suggests that fibre may inhibit cholesterol absorption by binding bile salts. Such binding could result in a failure in micellar formation, essential for cholesterol absorption, and this, in turn, would increase bile acid excretion, effecting an increase in bile acid synthesis to replace the lost bile salts. Both events would drain cholesterol pools (Kritchevsky and Story, 1974).

Water-holding and cation-exchange properties of fibre may also influence absorption of cholesterol and bile acids (McConnell et al, 1974).

The accumulated data indicate a general hypolipidaemic and anti-atherogenic effect. However, the type of fibre is important, for example lignin actively binds bile salts in vitro, cellulose does not (Kritchevsky and Story, 1974).

Dietary Fibre and Colon Function

(1) Effect on Stool Weight: Fibre, especially from bran, leads to softer, heavier stools. The increase in weight appears to be due to an increase in water content of the stool (Eastwood et al, 1973). Fruits and vegetables as absorbers are: turnip < potato < banana < cauliflower < pea < winter cabbage < lettuce < apple < carrot < mango < bran (McConnell et al, 1974). Particle size is also important – coarse bran holds more water than fine bran (Kirwan et al, 1974).

The constituents of fibre responsible for the absorption of water have not been conclusively identified. Probably the polysaccharide content is involved.

The bulking action of dietary fibre will have the added effect of diluting colonic contents, e.g. bile acids, which according to Burkitt (1974) should lower the risk of colonic cancer.

(2) Effect on transit time: Rural Africans who have a high fibre diet not only produce large, bulky stools, but are reported to have fast transit times, of the order of 30 hr, in contrast to Europeans and North Americans (< 48 hours) (Burkitt et al, 1972). Cereal bran, when given with the normal diet, not only causes an increase in stool weight, but also lowers transit times.

However, people with short transit times (<24 hours) react to bran by increasing their transit time (Harvey et al, 1973), perhaps suggesting that bran gives rise to an ideal "bran transit time", that will vary depending on the source of the vegetable fibre in the diet. The mechanism whereby fibre leads to a decreased transit time is not adequately explained. Vegetable fibre may alter the specific gravity of colonic contents; substances having a specific gravity of above or below 1.1 being more rapidly excreted than substances with specific gravity of 1.1 (Kirwan and Smith, 1974).

Epidemiology of Bowel Disease

Non infective bowel diseases include haemorrhoids, appendicitis, diverticular disease, cancer of the colon, colitis and Crohn's disease. It is thought that a deficiency of fibre coincides with their appearance.

With some bowel diseases, an excess of dietary fibre appears to coincide: volvulus of the colon and inflammatory bowel diseases (Cummings, 1973).

Many countries, e.g. some African, parts of India and Japan (Burkitt et al, 1974) appear to be free of non-infective bowel disease. There is a temptation to ascribe these characteristics to race. However, when people from these areas migrate to a country with high incidence, they suffer the same rate of bowel disease as their adopted countrymen. This suggests an environmental cause (Burkitt, 1974a).

The reverse migration, people from high-incidence countries going to low-incidence areas, does not usually result in a decreased incidence of colonic disease (Burkitt, 1974a).

It is unlikely that people from affluent countries would become less prosperous on moving to poorer countries. Thus non-infective bowel disease appears to be an environmental disease, and the component of the environment concerned appears to be connected to affluence.

Strong arguments exist that food is the environmental factor involved (Burkitt, 1974). Africans in low incidence areas derive 80% of their food energy from high fibre carbohydrates, mainly yams, millet and sorghum (Latham, 1965). In the West, the tendency over the past century or so has been towards an increased consumption of white flour (low in fibre), coupled with a dramatic rise in white sugar consumption. Fat consumption has also increased in the West. There is a correlation between these changes in diet and the sharp increase in incidence of non-infective bowel diseases but the correlation is tenuous, due to lack of data on both changes in diet and changes in frequency of bowel diseases.

Cleave (1969) believes that increased consumption of sugar is the main factor. The evidence for this is not strong, consisting mainly of a correlation between increased sugar consumption and increased incidence of colonic disorders.

Dietary Fibre and Diverticular Disease

This condition is common in Western countries but uncommon among Africans eating a high fibre diet (Painter and Burkitt, 1975).

It has been postulated that low fibre diets lead to the formation of small, hard stools which exert excessive pressure on the colon, causing small pockets or diverticula to be formed (Burkitt, 1974a).

It is estimated that a majority of people over the age of 60 years in Western countries have diverticula in the colon. However, only about 10% ever suffer symptoms (Painter and Burkitt, 1975).

Burkitt (1974a) suggests that bran should be added to the diet to protect against diverticular disease. Bran is the most concentrated form of fibre; it consists of about 21% cellulose, 20-26% pentosan (hemicellulose), 7.5-9.0% starch, 5% sugar, 11-15% protein, 5-10% fat, 5-9% ash and about 14% moisture (Kent-Jones and Amos, 1967).

That bran is beneficial in the treatment of diverticular disease is unquestionable. Many studies have shown improvement of patients after consuming

bran supplements (Burkitt, 1974a). It is highly likely that vegetable fibre will have a similar effect to that of bran; studies have not yet been carried out.

The problem of aetiology of diverticular disease is not solved by the finding that fibre will alleviate diverticular disease. It is possible that the cause of diverticulosis is something other than lack of fibre; there is no doubt, however, that fibre is of therapeutic value.

Dietary Fibre and Colonic Cancer

There is widespread belief that diet and colonic cancer are related. The factor(s) that may be involved have not been established.

The low incidence of this cancer in Africa (e.g. in Nigeria, 6/100,000) compared with North American Negros (70/100,000) suggests an environmental cause (Burkitt et al, 1972).

The rate of stomach cancer, in contrast, remains the same as in the country of origin (Drasar and Irving, 1973).

Burkitt (1974a) suggests that low levels of dietary fibre can lead to longer transit times and that bacteria in the colon can produce carcinogens from metabolites in the colon. The longer transit time would allow more of the carcinogens to be produced and would lead to a longer time of exposure to the carcinogens. Bile acids have been proposed as one substrate which bacteria may metabolise to produce carcinagenic by-products.

There are data to support the theory that carcinoma of the bowel is related to an enhanced faecal bile acid exretion (Hill et al, 1975). Cholesterol metabolism and colonic carcinoma may be inter-related. When there is an excess of serum cholesterol, it is converted to bile acids, which pass to the colon (Danielsson, 1973). Patients with large bowel cancer had higher faecal bile acid concentrations than the controls. More cancer patients also had nuclear dehydrogenating bacteria (Hill et al, 1975).

However, the correlation between low dietary fibre and cancer of the colon is weak.

Hill (1971) showed that the amount of bile acid in the faeces is dependent on the fat content of the diet. This may provoke a dilemma to heart patients who are urged to take polyunsaturated fats which lower the serum cholesterol level, but lead to increased faecal bile acid excretion.

Thwe et al (1976) found no significant difference in bacterial flora and daily excretion of bile acids in fast transit (<24 hrs) and slow transit (<48 hrs) people.

Because of the water-holding capacity of fibre, stools formed by people on high fibre diets tend to be much heavier (about 500 g) than those formed as a result of low-fibre diets. Thus Findlay et al (1974) showed that when the diet was supplemented with 20g bran per day, stool weight increased, but the concentration of bile acids decreased. This dilution of potential carcinogens may be of significance in reducing the risk of bowel cancer.

There is, however, a closer correlation between high fat and protein diets and cancer of the colon than between low fibre and bowel cancer (Wynder and

Shigematsu, 1967). Among potential carcinogens are several amino acids and lecithin, which may be converted to nitrosamine. N-nitroso compounds present in bacon, smoked fish and mushrooms may be converted to carcinogens (Lancet, 1973). Reducing agents, such as ascorbic acid, may have an unremarked protective effect by preventing the conversion of potential carcinogens to actual carcinogens.

The problem of carcinogenesis probably devolves on bacterial activity, to some extent, determining whether potential carcinogens are converted to actual carcinogens. Fibre will probably be important because of its dilution effects.

Fibre and Appendicitis

Studies in South Africa have shown a strong correlation between a diet high in fibre and low rates of appendectomy (Walker, A.R.P. et al, 1973). Among students in various parts of South Africa, rural Negroes had a rate of 0.5% appendectomy, Whites had a rate of 16.5%. In the cities, Negroes and Whites had similar appendectomy rates. Rural Negroes consume far greater amounts of vegetable fibre than either city Negroes or Whites.

Burkitt (1974) believes that a fibre-depleted diet can result in the formation of fecaliths and also excessive segmentation of the appendix, either of which may obstruct the appendix lumen. Obstruction might raise the intraluminal pressure sufficiently to devitalize the appendicular mucosa and allow bacterial invasion.

The evidence indicates that a change from a refined diet to one less refined is accompanied by a reduced incidence of the disease.

Fibre and Dental Caries

The common acceptance of the aetiology of dental caries as high sugar consumption is not supported by all the available evidence.

On the Island of Lewis (Scotland), white children consuming 100 g sugar per day had an average of about 2 decayed, missing or filled teeth (DMF) (King, 1940). White children in Johannesburg eating similar amounts of sugar had DMF of 10 (Retief et al, 1975).

Other evidence points to an increase in fibre consumption, as perhaps being of importance in the alleviation of dental caries. During World War II, the caries situation in children improved in all European countries (Bowen, 1972). The change was associated with a fall in sugar intake and a rise in consumption of fibre contained in cereals, vegetables and fruits. However, in Germany, dental caries also decreased, but this was in spite of a rise in sugar consumption (Wandett, 1969). This suggests that alterations other than a decrease in sugar intake were instrumental in effecting a reduction in dental caries. As with Western Europe, the diet increased in fibre in Germany during the war.

Conclusion

The "Fibre hypothesis" at present is more of an association than a relationship; that is, correlations have been shown to exist between various diseases and a decrease in dietary fibre.

Fibre undoubtedly has a therapeutic value in diverticulosis and at least eases the discomfort of haemorrhoids. Whether a fibre deficiency is involved in the aetiology of all or some of the diseases discussed above is, as yet, unproved.

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